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GASOLINE-BENZENE FUEL FOR AUTOMOBILE ENGINES IN THE USSR

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/Table and figures are appended; all degrees are centigrade./

Autombile transport in the USSR is receiving not only gasoline but also benzene as fuel for carburetor engines. The benzene is used in mixtures with gasoline, and the quality of the mixture is determined by the amount of each entering into its composition. In the TsNIIAT (Central Scientific Research Institute of Automobile Transport) tests were made of different gasoline-benzene mixtures to check the suitability of their properties under operating conditions.

To obtain the experimental mixtures, a nonethyl gasoline was selected which had separated out when the temperature at the end of the distillation was 205 degrees. A bituminous coal benzene at present being supplied to automobile transport was used to combine with this gasoline. The characteristics of these fuels are in the appended table. Distillation curves of the two fuels and various mixtures of them are shown in the graph in Figure 1.

This graph gives distillation curves for straight gasoline, straight benzene, and for the following mixtures: 85 percent gasoline and 15 percent benzene; 75 percent gasoline and 25 percent benzene; 65 percent gasoline and 35 percent benzene; 50 percent gasoline and 50 percent benzene.

The distillation curves indicate that the addition of benzene to gasoline in no way increases the temperature at the beginning of the distillation but considerably improves the course of all the remaining parts of the curves. Even the 10 percent point for mixtures containing 50 percent benzene and less is completely satisfactory. Points further on are more favorable for gasoline-benzene mixtures than for straight gasoline. This gives evidence of the increase in vapor pressure of saturated vapors of all fractions of gasoline-benzene mixtures except for the lightest top fractions.

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However, it must be remembered that the vaporizability of fuels in carburetor engines depends not only on the fractional composition and vapor pressure but also on the heat of vaporization and the amount of air in the working mixture.

The heat of vaporization of benzene is higher than that of gasoline (more than 40 percent higher at 20 degrees). This creates difficulties in the vaporization of benzene. If used in its pure form, a more thoroughgoing preheating of the intake manifold is required and starting the engine is difficult. Because of the high heat of vaporization of benzene, the temperature in the intake manifold is greatly lowered. In starting the engine when the temperature of the outside air is even 10 degrees, it is observed that the benzene congeals in the fuel atomization system, with the precipitation of crystals particularly in the diffuser of the carburetor, in the baffle plate, etc. However, for a mixture containing 30 percent benzene, the heat of vaporization is only 10-12 percent higher than for gasoline (under the same conditions). With a further decrease in the benzene content of the mixture, the heat of vaporization is also decreased.

For the complete combustion of one kilogram of benzene 13.2 kilograms of air are required, as against 15 kilograms for gasoline, that is, 12 percent less (by weight) than for gasoline. This impairs the vaporizability of benzene in carburetor engines. However, gasoline-benzene mixtures require more air for combustion than benzene does. Thus, for the combustion of a mixture containing 35 percent benzene, 14.4 kilograms of air are needed, or 4 percent less than for the combustion of gasoline, and for the combustion of a mixture containing 25 percent benzene, 14.55 kilograms of air are required, or 3 percent less than for straight gasoline.

The negative qualities of benzene (the increased heat of vaporization and the somewhat smaller amount of air required for combustion) which impair its vaporization in engines decrease when it is used in mixture with gasoline. At the same time, the vapor pressure from benzene-gasoline mixtures is higher than that of straight gasoline. This compensates for the negative qualities mentioned above from the standpoint of fine vaporization of the mixture in the carburetor engine. Mixtures containing up to 25-30 percent benzene are satisfactory for use in automobiles in summer in the central belt of the USSR.

To estimate the carburetion properties of gasoline-benzene mixtures the density, viscosity, and surface tension of the mixtures must be considered since the flow of fuel from the jet tube and the atomization of fuel in the carburetor system of the engine depend on these. The density of benzene as shown in the table of characteristics is almost 20 percent higher than that of gasoline (at 20 degrees).

The viscosity of benzene as given in the table differs very slightly from that of gasoline. The difference in the viscosity of gasoline and gasoline-benzene mixtures is even less, and from the viewpoint of its influence on the flow of fuel from the jet tube it can be disregarded.

The surface tension of benzene at 20 degrees is 27 percent higher than that of gasoline (see table) but, as regards the absolute amount, it still is not high (two fifths of the surface tension of water). The surface tension of gasoline-benzene mixtures is less than that of straight benzene. Consequently, atomization of mixtures containing up to 25-30 percent benzene is altogether satisfactory and is hardly at all inferior to the atomization of automobile gasoline.

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An important factor in estimating the possibility of using gasoline-benzene mixtures as fuel for automobile engines under USSR climatic conditions is the temperature at which the precipitation of benzene crystals is observed and the consequent interference with the operation of the engine. To assure dependable use of automobiles, it is necessary to select mixtures of such a nature that the temperature at which crystals are formed in them is definitely lower than the temperature of the air during the coldest part of the season in which the mixtures are to be used. At the same time, the length of the season during which the mixtures could be used should be as long as possible since replacing mixtures of one type with those of another necessitates a readjustment of the carburetor and other devices.

Technical benzene, in its pure form, crystallizes (congeals) at a temperature ranging from 5-5.4 degrees depending on its chemical purity and, consequently, use of it under USSR climatic conditions is excluded. However, the presence of gasoline in a mixture with benzene improves this situation, and with the increase of the gasoline content the temperature at which crystals are formed is lowered considerably. (See curve t_k in Figure 2.)

Gasoline-benzene mixtures containing up to 25-30 percent benzene and 70-75 percent gasoline are entirely satisfactory for their vaporizability and other carburetion characteristics for use in automobiles in summer in the central belt of the USSR. They are also completely satisfactory from the viewpoint of the low temperature at which crystals are formed (minus 30 degrees).

In considering the properties of gasoline-benzene mixtures, it is necessary to take into account the toxicity of benzene. Because of this, in 1949, provisional health regulations (No 114-242) approved by the Chief Health Inspector of the USSR established that the amount of benzene allowable for use in automobile fuel should not exceed 25 percent (by volume). This excludes the use of mixtures with a benzene content higher than 25 percent. Consequently, a mixture consisting of 75 percent gasoline and 25 percent benzene (by volume) should be recommended as fuel for summer automobile transport. At lower temperatures during the coldest part of the day a mixture with a benzene content of not more than 20 percent may be used. If the air temperature should drop below minus 25 degrees, but not below minus 40 degrees, the benzene content in the mixture must be reduced to 10-15 percent. Such mixtures in their carburetion characteristics and the temperature at which crystals are formed assure dependable operation of the automobile and reduce difficulties arising from the congealing of the benzene itself.

The use of benzene results in a large amount of deposit, and in gasoline-benzene mixtures the deposit, naturally, increases with the increase of the amount of benzene in the mixture. For this reason, too, it is best to limit the amount of benzene in the mixture to 25 percent.

The calorific value of benzene is lower than that of gasoline, being about 9,500 calories per kilogram. However, a gasoline-benzene mixture containing up to 25 percent benzene has a calorific value of 10,250 calories and is only slightly inferior in this respect to gasoline. Accordingly, the consumption of such mixtures in operating automobile engines approximates very closely the consumption of gasoline.

The antiknock stability of technical benzene is relatively high; its octane number determined by the motor method is 98-100 or higher. The presence of benzene in gasoline-benzene mixtures increases their antiknock stability, as is shown in Figure 3.

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At the same time, benzene burns more sluggishly in the engines (particularly low-compression engines), and the temperature of the cylinders, the bottom of the pistons, and the starting valves is increased. The gasoline-benzene mixture has this property to a lesser degree than straight benzene. However, in using it a greater spark advance is necessary than when operating on nonethyl gasolines. When there is an insufficient spark advance, there is a low burning of the working fuel on the line of expansion, and because of this superheating and a drop in the performance and efficiency of the engine. Thus, in converting automobile engines from gasoline to a gasoline-benzene mixture, in addition to regulating the fuel level in the float chamber and adjusting the carburetor to take the working mixture, assuring a good pickup of the automobile and efficiency in operation, it is necessary to pay proper attention to the spark advance.

/Appended table and figures follows./

Characteristics of Benzene and Gasoline Used to Obtain Mixtures

Physicochemical Properties	Benzene	Gasoline	Method of Calculation
Octane No OCh/M	98-100	57	GOST 511-46
Density at 20 degrees (g/cu m)	0.879	0.734	GOST 3900-47
Kinematic viscosity at 20 degrees (centistokes)	0.766	0.738	GOST 33-46
Surface tension at 20 degrees (dynes/cm)	29.0	22.8	P. A. Rebinder's method
Fractional composition:			
Beginning of distillation (degrees)	75	42	GOST 2177-48
10% distillation at (degrees)	79	74	
50% distillation at (degrees)	80	132	
90% distillation at (degrees)	80	187	
End of distillation at (degrees)	94	205	
Residue (percent)	1.6	1.5	
Losses in distillation (percent)	0.4	0.9	
Congelation point, (degrees)	Between 5 and 5.4	-1	OST 7872-39 MI-7l
Test on copper plate	Passed	Passed	GrozNII method
Acidity (mg KOH/100 ml)	2.88	1.91	GOST 1784-47
Water soluble acids and alkalies	Absent	Absent	OST 7872 MI 25 ye-37
Mechanical admixtures and water	Absent	Absent	OST 7872-39 MI-19v, GOST 2706-44, and GOST 2577-44

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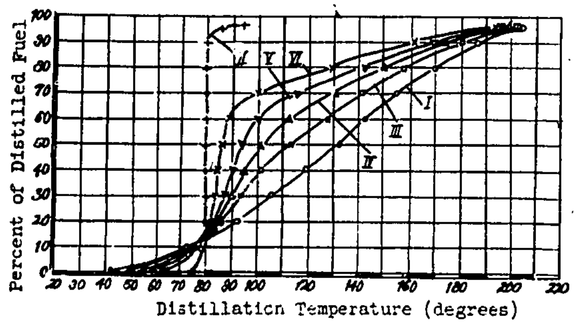

Figure 1. Distillation Curves for Gasoline (I), Benzene (II), and Mixtures Containing 85 Percent Gasoline and 15 Percent Benzene (III), 75 Percent Gasoline and 25 Percent Benzene (IV), 65 Percent Gasoline and 35 Percent Benzene (V), and 50 Percent Gasoline and 50 Percent Benzene (VI)

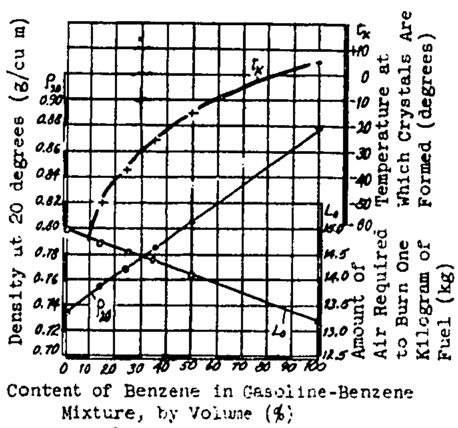

Figure 2. Density ρ20 (at 20 degrees), Temperature at Which Crystals Are Formed t_k, and the Amount of Air L_o (in kg) Required to Burn One Kilogram of Fuel for Gasoline-Benzene Mixtures in Different Combinations

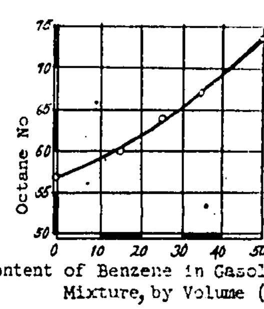

Figure 3. Octane Numbers of Gasoline-Benzene Mixtures in Different Combination

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